

# A framework for Quality improvement in Healthcare Information Systems

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**Abstract**—Bringing improvements to the quality in healthcare industries is a major concern of the health institutions. The healthcare information systems are adapted to improve number of healthcare complex processes such as complex patient flows, management of several healthcare units, and numerous human resources. Due to the high complexity in healthcare workflows and information processing, system analysis phase has become the most difficult and complex phase in the SDLC. This research responds to the question of how healthcare information systems could be improved by studying and enhancing the products, processes, services and resources. The suggested framework of HIS improvement contributes in providing a structured problem solving approach that helps software engineers to analysis the current problem, and in providing an improvement-approach that helps software engineers to convert the existing system’s workflow to an efficient one and improve its performance. Therefore, a framework for improving the health information systems through studying the workflow factors (Process, Product, Service, and Resource) is presented. This framework has been applied in King Fahad Medical City (KFMC) in the outpatient department to improve the outpatient appointment workflow and to suggest a solutions for late in date appointments and did not attend (DNA) situations. The framework has been validated through simulation to examine the effectiveness of the framework results.

**Keywords**— Healthcare Information System (HIS), HIS improvement, HIS quality improvement, HIS workflow, HIS analysis, quality improvement framework.

## I. INTRODUCTION

**N**OWADAYS, bringing improvements to the quality in healthcare industries is a major concern of the health institutions. Quality assurance strategies and activities applied into software development determine the success of the software in the healthcare domain [1]. Healthcare Systems are one of the most important segments of modern society. Improving the quality of health systems leads to providing effective care, and improving the quality of the care provided will improve the population's health [2].

Although, there are much research conducted in Healthcare systems quality improvement area, but there is no comprehensive framework on how to improve the quality of healthcare information systems. This study proposes a framework to improve the healthcare information system’s workflow quality; by focusing on the main components of the

system processes, products, services, and resources.

## II. RELATED WORKS

### A. Healthcare Information System

Today, Information System (IS) is a vital element in most fields of endeavor, whether it is healthcare, business, education, research or any other areas. An increasing number of daily live activities require the use of information system. The ultimate success or failure of a business depends on the following: offered services, increased productivity, reduce waste time, and achieved business objectives, and most importantly end user needs and expectations [3]. Currently, the use of Information Systems in Healthcare are significantly increased in both clinical and administrative processes where health related services are provided. The healthcare information system are adapted to improve number of healthcare complex processes such as complex patient flows, management of several healthcare units, and numerous human resources [4]. According to [5] HIS faces number of challenges such as irrelevance of the information gathered, poor quality of data, duplication and waste among parallel health information systems, lack of timely reporting and feedback, and poor use of information. Thus, according to [6] Healthcare system consist of three main components: (Resources/inputs: People, Infrastructure, Materials, Information, and Technology), (Activities/processes: What is done? And how it is done? ) and (Results/outputs/outcomes): Health services delivered, change in health behavior, change in health status and patient satisfaction).

### B. Quality Improvement in Healthcare

Healthcare Quality has been defined by the US Agency for Healthcare Research and Quality as “doing the right thing, at the right time, in the right way, for the right person—and having the best possible results” [7]. There are number of quality improvement approaches widely used in healthcare industry, such as six sigma quality improvement model [8] , PDSA quality improvement model [9] and Business Process Re-engineering approach [10].

### C. Healthcare Information System workflows

In healthcare, poor and ineffective use of the systems is associated with inattention to workflow [11]. [12] List a number of key recommendations for healthcare practitioners in defining clinical requirements, beginning with requirements

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development and extending through systems maintenance. One of the recommendations is analyze the system impact on the workflow by identifying the five W's: Who, What, Where, When, and Why for each activity and for all information has been collected and shared in the system. Moreover, it recommended that Avoid computerizing bad processes or creating poor workflow by workflow analysis to figure out the perfect opportunity to improve cumbersome processes. [13] Discuss the value of modeling and analysis the workflow in all its aspects: processes, information, applications and organization using PROTOS in medical IT project phases, taking the radiology Picture Archiving and Communication System (PACS) and the information management system in the cardiac echo lab implementation as an examples. Modeling and analysis the workflow provide a valuable assistance to understand the current situation, desired future situation and the effects of re-designing the work processes. [14] Added that the most important in analyzing healthcare workflow is to understanding and clearly defining the critical components who, what, where, when, why and how. Although, [15] added that Zachman framework was successfully modeled and identified the Estonian National Health Information System and its workflow.

*D. System reengineering and quality improvement*

Once the organization raise a problem in the current system and admit that it is no longer sufficient and effective, reengineering the system becomes a must. A proper analysis need to be done on the resources and the systems to get the benefits from the reengineering process and find the gap between the current system and the new one, otherwise it is not cost effective [16]. The software development life cycle (SDLC) in system engineering process consist of five main phases (Analysis, Design, Implementation, Testing, and Evaluation) this paper focus on the analysis phase. The Successful improvement of the system quality requires an efficient workflow analysis of the set of processes that must be achieved, the set resources and tools available to perform those processes in order to provide the patient services [17].

III. HEALTHCARE QUALITY IMPROVEMENT APPROACHES

*A. Six Sigma*

Six Sigma improvement model and business strategy which allows organizations to improve their outcomes by continuous improvement, begun used in healthcare industries since around 2000. Define, Measure, Analyze, Improve and Control (DMAIC) methodology offered by six sigma to improve the system output and outcome by find the problem root causes to eliminate defects and reduce the variation in processes [18]. DMAIC steps consist of a key process to control the implementation of each step, we gather these keys shown in the figure below from [19].

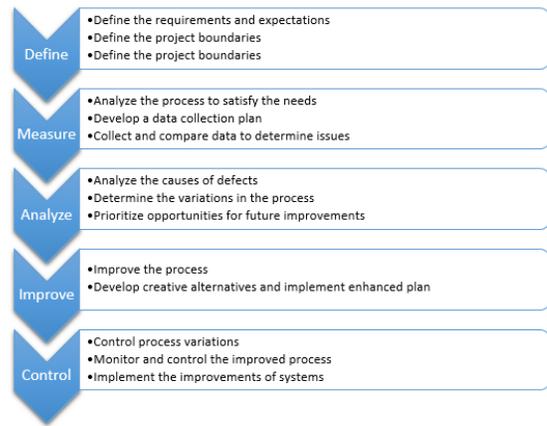


Fig. 1 DMAIC steps

*B. Plan, Do, Study, Act (PDSA)*

Plan-Do-Study-Act (PDSA) model propose by Institute of Healthcare Improvement (IHI) to introduce the continuous quality improvement (CQI), this tool adapted from the 1970s [18]. PDSA quality improvement model answer three questions: What are we going to accomplish? How will we know if a change is an improvement? and what change can we make that will result in an improvement?

Although, this model consist of four steps of the continuous improvement cycle. PDSA cycle contains four steps shown in figure 3 [7]:

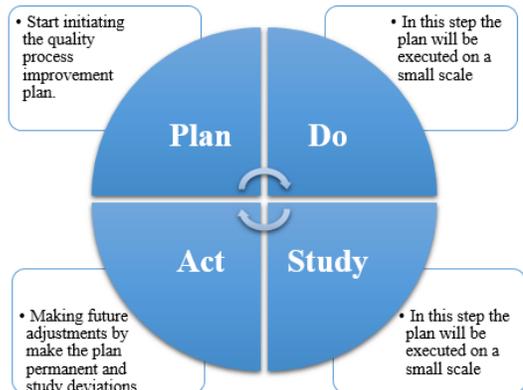


Fig. 2 PDSA steps

*C. Business Process Reengineering (BPR)*

BPR show up in the US in the 1990s, it is an approach of workflow redesign, defined as a management method which redesign and redevelop exist practices and processes in business and its interactions. It aims to improve the process efficiency by applying essential approaches by modifying or eliminating non-value adding activities. This approach use to analysis and redesign the processes in order to improve the workflow quality and services [10]. BPR consist of five main steps [18]: Identify the BPR objectives, Analysis the As-Is process, Identify weaknesses and opportunities, Design To-Be process and Improve the Process and analysis the new changes.

Moreover, many tools available to facilitate BPR process such as Unified Modeling Language (UML) and Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis

tools. UML tool allow the engineer to model and design the workflow visually and help to understand and simplify the flowcharting of complex processes [10]. In the other hand, SWOT help the engineer to understand and analysis factors that influence the organization process. This tool will grant the engineer the ability to capitalize the strengths and opportunities and minimizing the weaknesses and threats [20]

#### IV. RESEARCH METHODOLOGY

An applied research methodology used in this paper matching with existing pre-knowledge and theories available within the scientific community to answer the research question. A new framework will be proposed to improve the quality of healthcare information systems. The developed framework will be applied in a case study that is (King Fahad Medical City Health Information System – new generation-project) and validated through a simulation method. This framework expected to be applied in the information technology (IT) department in healthcare industry. The research and framework development methodology will follow different methods to find the best way to improve the information systems in healthcare:

- A collection of recent research papers documents that discussing the idea of improving health information system quality have been collected, and reviewed.
- A number of Observations throughout hospitals to gain insight in improvement practices, these observations were performed by visiting IT department in the hospitals and observing the way of enhancing and improving the health information systems.
- A case study has been conducted in the outpatient department in King Fahad Medical City in Riyadh, kingdom of Saudi Arabia to ensure that the goals of the proposed framework are being met.
- Using a qualitative and a quantitative approach during a case study through conducting multiple interviews and surveys with the people in the concerned field, to figure out their prospective and views to improve the quality of healthcare information systems.

#### V. FINDINGS

##### A. Findings from the literature review

Earlier in the related work section, number of the related models have been discussed. In order to improve the healthcare system this study focused on the concepts of defining the problem, analysis the current situation, analysis the Strengths, Weaknesses, Opportunities and Threats (SWOT) of the current situation, and solve the problem by improve the current workflow. The six sigma, business process reengineering and Zachman models cover these concepts. Six sigma help to define and improve the problem [19], business process reengineering determine the current workflow [10] and analyze it using SWOT analysis tool [20], Zachman model help to do a proper analysis of the current workflow factors (process, product, service and resource) [15].

##### B. Findings from the observation

As mentioned in the methodology that a number of observation have been conducted in the IT department at three different hospitals, to observe how the existing systems can be improved. In hospital (1) usually IT department receive a change request from the hospital departments such as outpatient, inpatient, and pharmacy to enhance the HIS. This request contains various information that help the engineers to understand the request and the required changes such as:

- The current process of how the system currently functions.

- The exact products will be changed.
- The desired function that requested to be implemented.

The system manager will check this request, if it is applicable then changes will be implemented by the engineer. Otherwise this request will be rejected. In hospital (2), HIS users have to meet the IT representative in order to request any change. Usually users start defining their problems and the most of the changes are discussed during the meeting verbally and no documents are produced for the desired changes. The requested changes are applied without any study. In hospital (3) IT department will receive the change request and the engineers will start gathering the requirements and implementing the changes. In this hospital there is no study of the current situation, only the requirements document. By observing these hospitals, following findings came into light:

- Problems are not well defined at the beginning, so in this case a solution that is implemented maybe not be the proper solution
- If the current process, product, service, and resources are not determined, many confusion in the system functions at the development stage and sometimes requester ask for some changes which is already in the system but he is not fully aware or trained.
- If the change requested is not applicable in the system a lot of time wasted in the requirement gathering, because the request is not based on the user and engineer's point of view.
- Lack of documentation led to develop the enhancement wrongly.

#### VI. PROCESS, PRODUCT, SERVICE, AND RESOURCE (PPSR) FRAMEWORK

This section presents the proposed framework for improving the healthcare information systems. As discussed earlier, the focus of this framework is to improve the current systems workflow by studying the influencing factors: Process, Product, Service, and Resource. Following is a decomposition of the suggested framework steps:

TABLE I  
PROCESS, PRODUCT, SERVICE, AND RESOURCE (PPSR) FRAMEWORK

Steps	Elements	Objectives	
<b>Problem definition</b>	Problem	What is the problem?	Define the current problem which need to be solved through the system and the reason behind this improvement.
	Goal	What are we going to accomplish?	
<b>Current situation</b>	Workflow	What is the current workflow?	Determine and analyze the current workflow and all the processes, products, services and resources within the current situation which affect the study of the problem.
	Process	How it's done?	
	Product	What to use?	
	Service	What to provide?	
	Resource	By whom?	
<b>SWOT analysis</b>	Strengths	What is the Strengths of the current situation?	Using "SWOT" technique to find the problem cause from the determined factors.
	Weaknesses	What is the Weaknesses of the current situation?	
	Opportunities	What is the Opportunities of the current situation?	
	Threats	What is the Threats of the current situation?	
<b>Improvement</b>	Solution	How the weaknesses can be improved?	Suggest a solutions which could solve the problem and optimize the current workflow. Moreover, describe the suggested solution and the required changes in the aspects: process, product, service and recourse to provide a well-defined and clear solution
	Process	What are the changes on the process?	
	Product	What are the changes on the product?	
	Service	What are the changes on the service?	
	Recourse	What are the changes on the recourse?	

VII. KING FAHAD MEDICAL CITY (KFMC) CASE STUDY

A. King Fahad Medical City

KFMC in Riyadh the capital city of Saudi Arabia, considered as the largest advanced medical complex in the Middle East with capacity of 1095 beds covered four hospitals (Main, Rehabilitation, Children's, and Maternity). KFMC expect to treat annually more than 50,000 in-patients and over 600,000 outpatients [21].

Currently, KFMC are in the process of improving the exist HIS and to produce a new generation. This project will cover a number of new features that help to solve the current problems and reach their main object to provide every Saudi citizen with

the best health care service. One of the project goals is to improve the appointment module in order to solve the most important issue which is the appointments' late in date.

This section will discuss the execution and the application of the proposed framework on the selected case study King Fahad Medical City (KFMC) – outpatient department.

B. Framework application

1. Problem definition

What is the problem?

The main problem, which is the late in date appointments and did not attend (DNA) patients have been discussed with the outpatient department manager in KFMC. Due to the full list of appointments, patients cannot find enough appointments available to meet their demand so they supposed to have appointment late in date even though the DNA percentage is high, 30% of the patients in six month did not attend their appointments. Some of the clinics have full appointments list and the nearest available appointment is after two years from now in 2017. During this long time, a number of possibilities might be happen, patient may get treatment in other hospitals while his appointment in KFMC still booked, patient situation may worsen in this period, or the doctor may left the hospital in this period of time, this leads to reschedule all patient's appointments under his supervision.

What are we going to accomplish?

The main goal is to find a solution to improve the current outpatient appointment workflow to solve the problems by reduce the DNA percentage and increase the available appointments slots.

2. Current situation

What is the current workflow?

Currently, once the appointment has been requested by patient, the responsible staff will check the appointments schedule and will inform the patient with available date and time. Patient acceptance is required to move on and book an appointment using HIS outpatient appointment module. Then before three days from the appointment date, patient will receive a remainder message request him to contact the hospital in case of cancelation or rescheduling. Otherwise, if he did not attend the appointment will marked as DNA.

TABLE II  
WORKFLOW FACTORS

Workflow	Outpatient appointments
<b>How it's done? (Process)</b>	<ol style="list-style-type: none"> <li>Booking process</li> <li>Cancel process</li> <li>Reschedule process</li> </ol>
<b>What to use? (Product)</b>	<ol style="list-style-type: none"> <li>HIS:                         <ul style="list-style-type: none"> <li>Outpatient                                 <ul style="list-style-type: none"> <li>Appointments module</li> </ul> </li> </ul> </li> <li>SMS system.</li> </ol>
<b>What to provide? (Service)</b>	<ol style="list-style-type: none"> <li>Appointment reminder by SMS</li> <li>Book, cancel, reschedule an appointment by Walk-in or call KFMC</li> </ol>
<b>By whom? (Resource)</b>	<ol style="list-style-type: none"> <li>Receptionist</li> <li>Patient</li> </ol>

### 3. SWOT analysis

The strengths, weaknesses, opportunities, and threats (SWOT) of the determine factors have been analyzed:

TABLE III  
SWOT ANALYSIS

<b>Strengths</b>	Well trained HIS users Remainder service by SMS Well defined appointments processes
<b>Weaknesses</b>	No alternative list No confirmation process Long appointments schedule
<b>Opportunities</b>	Integrated HIS and SMS system Improvable appointments processes HIS is an adjustable system
<b>Threats</b>	Limited integration with IVR system Patients attitude

### 4. Improvement

#### How the weaknesses can be improved?

In this part, the suggested solution will be discussed in detail based on the required changes in the four factors. Based on the above findings, this research suggests adding a waiting list as an alternative list, adding a limitation in the appointment schedule so it will be open for a period, for instance three months, implement voice reminder messages, and establish an appointment confirmation process.

## VIII. VALIDATION

### A. Adjustment

The appointments data of two weeks in KFMC’s hospitals has been collected for the period of 30 November to 11 December 2014. Table IV show the Number of booked appointments (A), number of did not attend (DNA) patients (B), number of show patients (C), number of walk-in patients (D), and total seen (E).

TABLE IV  
APPOINTMENTS DATA FROM 30 NOVEMBER TO 11 DECEMBER IN KFMC HOSPITALS / CENTERS

Hospital / center	(A)	(B)	(C)	(D)	(E)
<b>Main Hospital</b>	3087	1893	1194	1251	3144
<b>Rehabilitation Hospital</b>	2015	1661	354	83	1744
<b>Women Specialized Hospital</b>	1150	879	271	441	1320
<b>Children's Hospital</b>	1123	731	392	239	970
<b>National Neuroscience Institute</b>	614	404	210	117	521
<b>Prince Salman Heart Center</b>	669	467	202	133	600
<b>Obesity, Endocrine And Metabolism Center</b>	560	389	171	135	524
<b>Comprehensive Cancer Center</b>	362	267	95	86	353

An adjustment will be applied to the number of DNA

patients for all KFMC hospitals for two weeks to validate the suggested cancellation process through IVR and describing IVR again in brief. Simulating 1%, 3%, 5%, 7%, 10%, or 15% of DNA patients cancelling their appointments through IVR, number of available appointments will be increased as shown in table V. This simulation shows that the number of available appointment slots in the system will increase if the DNA patients cancelled their appointments before the appointments date.

TABLE V  
ADJUSTMENT FOR CANCELLED APPOINTMENTS THRU IVR BY DNA PATIENTS

Hospital / center	Number of cancelled appointments					
	1 %	3 %	5 %	7 %	10 %	15 %
<b>Main Hospital</b>	12	36	60	84	119	179
<b>Rehabilitation Hospital</b>	3	11	18	25	35	53
<b>Women Specialized Hospital</b>	3	8	14	19	27	41
<b>Children's Hospital</b>	4	12	20	27	39	59
<b>National Neuroscience Institute</b>	2	6	10	15	21	31
<b>Prince Salman Heart Center</b>	2	6	10	14	20	30
<b>Obesity, Endocrine And Metabolism Center</b>	2	5	9	12	17	26
<b>Comprehensive Cancer Center</b>	1	3	5	7	9	14

### B. Results of the questionnaires

Two questionnaires have been conducted, staff questionnaire and patient questionnaire. These questionnaires have been distributed to different patients who are getting their treatment in KFMC and to the receptionists. Feedback obtained in result of distributed questionnaire helped us to get to our solution in an effective way. The questionnaire for receptionists generated 26 responses and for patients generated 82 responses, with variant education levels of the participants, having the majority of responses from Riyadh city of (57.32%).

#### 1. Patient questionnaire

Table VI shows the result of the patient questionnaire in percentages. 82 response has been collected from different KFMC’s patients. The questionnaire consist of 8 statements and 5 different values ordered from highest to lowest (strongly agree, agree, nature, disagree and strongly disagree).

Statements:

- 1) when I request an early appointment, it won't be available for me
- 2) I had previously booked an appointment and could not attend it
- 3) I do reschedule my appointment or cancel it when I'm not being able to attend
- 4) I was able to get into the clinic without booking an appointment as walk-in patient

- 5) I prefer reminding me about the appointment by a voice message
- 6) Most of my appointments are late in date
- 7) I prefer to book a partial appointment in the waiting list than booking a late appointment
- 8) I prefer to be contacted to confirm the partial appointment instead of waiting at the hospital.

TABLE VI  
PATIENT QUESTIONNAIRE RESULTS

State ment	Strong ly Agree	Agree	Nature	Disagree	Strongly Disagree
(1)	12%	32%	18%	32%	6%
(2)	6%	44%	6%	30%	13%
(3)	11%	13%	11%	56%	9%
(4)	10%	34%	15%	29%	12%
(5)	38%	26%	10%	20%	7%
(6)	22%	30%	21%	21%	6%
(7)	30%	32%	13%	18%	6%
(8)	37%	26%	17%	16%	5%

2. Staff questionnaire

Table VII shows the result of the staff questionnaire in percentages. 26 response has been collected from different KFMC’s receptionists. The questionnaire consist of 7 statements and 5 different values ordered from highest to lowest (strongly agree, agree, nature, disagree and strongly disagree).

- 1) Patients usually contact the hospital in order to cancel their appointments.
- 2) Patients usually contact the hospital in order to reschedule their appointments.
- 3) Can adding a waiting list to the system will reduce the number of ‘Did Not Attend’ patients.
- 4) A Large percentage of Patients are walk-in patients
- 5) Can applying the concept of One-Week Schedule will prevent the late appointments
- 6) Can the Voice reminder Messages with confirmation, cancelation, and rescheduling through IVR system reduce number of ‘Did Not Attend’ patients
- 7) Would you prefer to receive emails with appointment rescheduling requests

TABLE VII  
STAFF QUESTIONNAIRE RESULTS

State ments	Strongl y Agree	Agree	Nature	Disagree	Strongly Disagree
(1)	4%	15%	31%	19%	31%
(2)	4%	27%	35%	23%	12%
(3)	0%	42%	31%	27%	0%
(4)	19%	62%	15%	4%	0%
(5)	4%	46%	46%	4%	0%
(6)	12%	50%	31%	8%	0%
(7)	12%	46%	19%	23%	0%

C. Summarizing the simulation scenario

A simulation scenarios will applied on the Main Hospital of KFMC for the suggested solution. Below table show the

mentioned data for the period of 30 November to 11 December 2014 which has been collected.

TABLE VIII  
MAIN HOSPITAL DATA

	booked appointments	show up patients	DNA patients
Main Hospital	3087	1893	1194

The scenario is: Assuming the following number of booked appointments and number of patients show-up during 10 days:

TABLE IX  
ASSUMPTION: APPOINTMENT DATA IN MAIN HOSPITAL DURING 10 DAYS

Day	Booked appointments	Show-up patients	DNA patients
1	331	215	116
2	310	100	210
3	290	208	82
4	405	315	90
5	335	217	118
6	254	110	144
7	403	243	160
8	203	119	84
9	313	203	110
10	243	163	80
Total	3087	1893	1194

An adjustment of the DNA patients canceled the appointment thru IVR few days before the appointment date. The table below shows that the number of available appointments slots is increased once the DNA patients cancel their appointment before the appointment date.

TABLE X  
ADJUSTMENT OF THE DNA PATIENTS IN MAIN HOSPITAL

Day	Number of canceled appointments (available slots)						
	1 %	2 %	3 %	5%	7%	10 %	15 %
1	≈1	≈2	≈3	≈6	≈8	≈12	≈17
2	≈2	≈4	≈6	≈11	≈15	≈21	≈32
3	≈1	≈2	≈2	≈4	≈6	≈8	≈12
4	≈1	≈2	≈3	≈5	≈6	≈9	≈14
5	≈1	≈2	≈4	≈6	≈8	≈12	≈18
6	≈1	≈3	≈4	≈7	≈10	≈14	≈22
7	≈2	≈3	≈5	≈8	≈11	≈16	24
8	≈1	≈2	≈3	≈4	≈6	≈8	≈13
9	≈1	≈2	≈3	≈6	≈8	11	≈17
10	≈1	≈2	≈2	4	≈6	8	12
Total	12	24	35	61	84	119	181

IX. DISCUSSION AND CONCLUSION

The process, product, service, and resource (PPSR) framework has been applied into the outpatient department of KFMC. In the case study, a number of suggestions have been given in order to improve the current HIS. Patients and receptionists have been asked about these suggestions in order to check the validity of the framework.

The first solution is to add waiting list as an alternative list to the appointments list. 42% of the receptionists agreed that the waiting list can reduce the number of ‘Did Not Attend’

patients, and 62% of the patients preferred to be in the waiting list rather than book late appointment. The second suggestion is to add a limitation in the appointment schedule, so the schedule will be open for a period of time. 50% of the receptionists welcoming this idea and agree that this can provide more available appointments' slots. Finally, the third and fourth suggestions is to establish an appointment confirmation process with an IVR system. 62% of the receptionists agreed on that this new process can be helpful to reduce the DNA patients. In addition 64% of the patients preferred to be reminded about their appointment by a voice message. Moreover, 50% of the receptionists agreed that patients rarely contact the hospital in order to cancel their appointments. Therefore, these results prove the effectiveness of the framework application results in improving the HIS quality and solve the proposed problem.

In conclusion, this research makes important contributions to Healthcare Information Systems research and practice. This study proposes a quality improvement model of the healthcare information system. Moreover, it extends the current HIS quality improvement literature to include the perspective of workflow and its factors improvements. The main research question has been defined as follows: "How to improve existing healthcare information system workflow by focusing on the product, process, service, and recourse?"

In an attempt to answer this question, the research has explored the literature and related works of information system quality, software quality, and the available approaches that have been developed to improve the HIS, to study and understand existing quality improvement models and frameworks for both healthcare and software. Furthermore, based on the study of the existing models and frameworks and based on the conducted observations and case study, a framework for quality improvement in healthcare information systems has been developed to improve the quality of the healthcare systems to provide high quality services for healthcare outcomes. The experimentation on the PPSR Framework for HIS quality improvement was developed to validate the proposed framework in line with an adjustment approach, proves that applying the framework on a KFMC case study improves the HIS workflow. It provides a precise study of the system problem and therefore, the workflow factors.

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